भारतीय मानक
Indian Standard

IS 14496 (Part 1) : 2020

पर्वतीय भूभाग में भू-स्खलन आपदा के समक्ष क्षेत्रीय मानचित्रों की तैयारी — मार्गदर्शी सिद्धांत

भाग 1 मेसो-क्षेत्रीय

Preparation of Landslide Hazard Zonation Maps in Mountainous Terrains — Guidelines

Part 1 Meso-Zonation

ICS 07.040

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Hill Area Development Engineering Sectional Committee, CED 56

FOREWORD

This Indian Standard (Part 1) was adopted by the Bureau of Indian Standards, after the draft finalized by the Hill Area Development Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

The mountainous terrains, such as Himalayas are generally characterized by steep slopes, high relative relief, weathered, fractured and folded rocks with unfavourable hydrogeological conditions. The implementation of development schemes like road, dam, building construction, etc, often cause heavy environmental damages if the existing instabilities are not adequately accounted for.

A landslide hazard zonation (LHZ) map divides the land surface into zones of varying degrees of stability, based on the estimated significance of causative factors in inducing instability. If such multi-purpose terrain evaluation maps are used as a basis of preliminary planning of the development schemes, it will help to select geo-environmentally sound sites which may pose minimum hazards of instability. The LHZ maps are prepared based on the basic causative factors of slope instability. The LHZ maps are useful for the following purposes:

a) To identify and delineate unstable hazard-prone areas, so that environmental regeneration programmes can be initiated adopting suitable mitigation measures, and
b) To help planners to choose favourable locations for citing development schemes, such as, buildings, dam and road constructions. Even if the hazardous areas cannot be avoided altogether, their recognition in the initial stages of planning may help to adopt suitable precautionary measures.

The Committee responsible for the formulation of this standard decided to formulate this standard into two parts to cover different scales of mapping and to cover different extents of details as required depending on the nature of various projects. This standard (Part 1) 'Meso-zonation', covers a scale of 1 : 5 000 to 1 : 10 000.

This Indian Standard is published in two parts. The other part in this series is:

Part 2 Macro-zonation (covering a scale of 1 : 25 000 to 1 : 50 000)

In the formulation of this standard, assistance has been derived from Mountain Risk Engineering Handbook, International Center Integrated Mountain Development.

The composition of the Committee responsible for the formulation of this standard is given at Annex A.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 1960 'Rule for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be same as that of the specified value in this standard.

Indian Standard

PREPARATION OF LANDSLIDE HAZARD ZONATION MAPS IN MOUNTAINOUS TERRAINS — GUIDELINES

PART 1 MESO-ZONATION

1 SCOPE

This standard (Part 1) covers guidelines for preparation of meso-scale Landslide Hazard Zonation (LHZ) maps on 1 : 5 000 to 1 : 10 000 scale.

NOTE — The meso-scale LHZ maps are useful for local planning of infrastructures and town planning in hilly areas. The scale is appropriate for locating potential terraces for construction purpose. During town planning or expansion of town limit or setting up of satellite townships in hills, this technique being more informative as compared to macro-zonation, will help to identify the hazard prone areas, where more detailed studies can be initiated. Wherever required the hazard prone areas can be avoided for better stability of the structures. The basic factors considered in this Code broadly remain same as that of macro-zonation with more details for better evaluation of the slope facets. This technique will also be useful to plan bye-pass roads for hill towns. The alternate communication routes in case of landslides, flood, fire and other natural hazards can be planned using this map.

2 REFERENCES

The standards listed below contain provisions which, through references in the text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
1893 (Part 1) : 2016	Criteria for earthquake resistant design of structures: Part 1 General provisions and buildings (*sixth revision*)
7422	Symbols and abbreviations for use in geological maps, sections and sub-surface exploratory logs
(Part 1) : 1974	Abbreviations
(Part 2) : 1974	Igneous rocks
(Part 3) : 1974	Sedimentary rocks
(Part 4) : 1985	Metamorphic rocks
(Part 5) : 1992	Line symbols for formation contacts and structural features
14496 (Part 2) : 1998	Guidelines for preparation of landslide hazard zonation maps in mountainous terrains: Part 2 Macro-zonation

3 FACTORS CONSIDERED FOR PREPARATION OF LANDSLIDE HAZARD ZONATION (LHZ) MAPS ON MESO SCALE

3.1 The landslide hazard zonation (LHZ) mapping on meso-scale shall be carried out in 1 : 5 000 to 1 : 10 000 scales. This zonation approach can be applied for systematic town planning in hilly regions, expansion of existing urban settlements including setting up of satellite townships in hills and other development purposes.

3.2 The smallest unit of study shall be a slope facet. A slope facet is a part of hill slope having similar slope characteristics (same amount of slope inclination and direction with a variation of ± 20° for both) and is usually bordered by natural features like ridges, spurs, gullies, depressions and rivers.

3.3 The inherent parameters of a slope facet shall be considered for study. Inherent parameters are those whose effect can be studied/assessed on the slope facet. These include lithology, structure, slope morphometry, relative relief, land use and land cover, and hydrogeological conditions. The hazard probability of a facet usually depends on the combined effect of all the inherent parameters. However, this approach also incorporates the effect of external parameters like seismicity and rainfall. External parameters are those factors whose effect cannot be assessed/studied on the slope facet. Many times they initiate slope instabilities and hence called triggering factors. They affect a large area for which they are also called regional factors. In other words because of their regional nature, their impact on a single facet cannot be assessed. For this, they are incorporated in LHEF rating scheme as separate correction factors.

4 LANDSLIDE HAZARD EVALUATION FACTOR (LHEF) RATING SCHEME

4.1 The LHEF rating scheme is an empirical rating scheme, which considers effect of all inherent causative factors as well as external factors namely seismicity and rainfall (*see* **3.2**), responsible for slope instability. The rating allotted for individual factors, as considered here, has been conceptualized from LHZ mapping on macro-zonation approach [*see* IS 14496 (Part 2)] with suitable corrections/modifications in the range of rating values for incorporating required details for meso scale (1 : 5 000 to 1 : 10 000) LHZ mapping. The maximum value of ratings for individual parameter is awarded keeping in mind its estimated significance in causing slope instability and also to represent overall field conditions. Like macro-zonation approach, in meso-zonation technique also, maximum sum of all the LHEF ratings is 10.0, that is this system is based on a 10 point additive scale of LHEF ratings (*see* Table 1).

4.2 Description of causative factors and their corresponding LHEF rating is given in **4.2.1** to **4.2.6**.

Table 1 Maximum LHEF Rating for Different Causative Factors

(*Clause* 4.1)

Sl No.	Causative Factors		Maximum LHEF rating
(1)	(2)		(3)
i)	Internal Factors:		
	Geology	a) Lithology	2.0
		b) Structure	2.0
	Slope parameter	c) Slope Morphometry	2.0
		d) Relative Relief	
		e) Land use and land cover	2.0
		f) Hydrogeological conditions	1.0
ii)	External Factors:		
		a) Seismicity	0.5
		b) Rainfall	0.5
	Total of LHEF Ratings (Inherent + External Factors)		**10.0**

4.2.1 *Lithology*

a) *Rock slopes* — The lithology is an important factor in controlling the stability of rock slopes and the maximum LHEF rating of 2.0 is given under this category. The lithology or rock type controls the nature and extent of weathering and its subsequent erosion. This point is given due consideration while awarding the rating. In this category, rocks are broadly classified into three classes:

   1) Type 1,
   2) Type 2, and
   3) Type 3.

   Type 1 rocks consist of crystalline (igneous and metamorphic) rocks along with massive calcareous rocks. These types of rocks are usually resistant to weathering (particularly physical weathering), resulting in steep slopes. Type 2 rocks mainly comprise well and poorly cemented terrigenous (clastic) sedimentary rocks. Type 3 category consists of soft argillaceous rocks and their low grade metamorphic equivalents and well foliated gneissic rocks. Soft rocks like claystone, siltstone, mudstone, shale, slate, phyllite and other such rocks erode much faster and are easily weathered close to surface. Moreover slate, phyllite and schistose rocks have well defined foliation plane along which sliding often takes place. Same is the case with gneissic rocks with thick foliated bands.

   In LHEF rating scheme, weathering of fresh rocks is also included as a correction factor which is to be multiplied to the rating of respective fresh rock, for Type 1 and Type 2. Type 3 rocks usually have an inbuilt higher rating, for which there is as such no requirement to multiply with the correction factor. But depending on condition of weathering the rating can be suitably modified to represent the field condition. The maximum value for rating of Type 3 rocks can be increased to 2.0 representing worst possible condition. The ratings for different rock types are tabulated in Table 2 and the weathering corrections for different rock types are tabulated in Table 3.

b) *Soil slopes* — Some hill slopes may be composed of loose soils and debris material. So, in slopes comprising loose overburden materials, genesis and relative age are considered as the main criteria while awarding rating. Older *in-situ* as well as alluvial soil is generally well compacted with high shear strength and also resistant to weathering. On the other hand hill-slide debris and younger incompact residual soil are generally loose with low shear resistance and erosion resistance which make them prone to further sliding activity. LHEF rating for different types of soil types are shown in Table 4.

Table 2 LHEF Rating for Rock Types

[*Clause* 4.2.1(a)]

Sl No. (1)	Category (2)	Rock Types (3)	Ratings (4)
i)	Type 1	Basalt, quartzite and massive limestone and dolomite	0.2
		Massive granite, gabbro and dolerite	0.3
		Massive granite gneiss and meta-volcanics	0.4
ii)	Type 2	Thickly bedded calcareous rock with intercalations of argillaceous rocks	0.8
		Well-cemented terrigenous sedimentary rocks (dominantly sandstone) with minor beds of clay stone and gneissic rocks	1.0
		Poorly-cemented terrigenous sedimentary rocks (dominantly sandstone) with intercalations of clay or shale beds	1.3
iii)	Type 3	Foliated gneiss	1.0
		Fresh to moderately weathered shale and slate	1.2
		Fresh to moderately weathered argillaceous rocks like siltstone, mudstone and claystone	1.4
		Fresh to moderately weathered phyllite	1.6
		Fresh to moderately weathered schistose rocks	1.7
		Highly weathered Shale and all other argillaceous rocks, phyllite and schistose rocks	2.0

Table 3 Correction Factors for Weathering

[*Clause* 4.2.1(a)]

Sl No.	Weathering condition	Description	Rating	
			Type 1	Type 2
(1)	(2)	(3)	(4)	(5)
i)	Completely weathered	Rock totally decomposed/disintegrated to soil, no or minor existence of initial rock structure (Correction factor, C_1)	$C_1 = 4.0$	$C_1 = 1.5$
ii)	Highly weathered	Rock totally discoloured, discontinuity planes show weathering products, rock structure altered heavily with minor soil formation near surface (Correction factor, C_2)	$C_2 = 3.5$	$C_2 = 1.35$
iii)	Moderately weathered	Rock prominently discoloured with remnant isolated patches of fresh rock, weathering and alteration prominent along discontinuity planes, considerable alteration of rock structure (Correction factor, C_3)	$C_3 = 3.0$	$C_3 = 1.25$
iv)	Slightly weathered	Rock partially discolored along discontinuity planes indicating weakening of rock mass, rock structure is slightly altered (Correction factor, C_4)	$C_4 = 2.5$	$C_4 = 1.15$
v)	Faintly weathered	Rock slightly discoloured along discontinuity planes which may be moderately tight to open in nature, intact rock structure with or without minor surface staining (Correction factor, C_5)	$C_5 = 2.0$	$C_5 = 1.0$

Table 4 LHEF Rating for Soil Type

[*Clause* 4.2.1(b)]

Sl No. (1)	Description (2)	Ratings (3)
i)	Older *in-situ* soil (elluvial), older well compacted fluvial fill material (alluvial)	0.8
ii)	Clayey soil with naturally formed surface (elluvial, alluvial, aeolian)	1.0
iii)	Sandy soil with naturally formed surface (alluvial)	1.4
iv)	Debris comprising mostly loose rock pieces mixed with clayey or sandy soil (colluvial):	
	a) Older, well compacted	1.2
	b) Younger loose material	2.0
v)	Younger, incompact residual soil (lying as thin cover on hill slopes)	2.0

4.2.2 *Structure*

a) *Rock slopes* — Stability of hill slopes consisting of in-situ rocks is largely dependent on the relationship between orientation of slope and attitude of dominant discontinuities. Structures include both primary and secondary discontinuities like bedding, foliation plane, schistosity, joints, shear zones and other such features. In this connection two types of failure modes, translational and toppling, are taken into account, since detailed stability analysis can be carried out for these types of failures. The other failures, such as falls, topples, flows and subsidence, if encountered may also be studied suitably. Translational failure include plane and wedge failures while toppling failure takes into account block topple and wedge topple. For individual failure modes, three types of conditions exist between the slope and the most unfavourable discontinuity plane or the line of intersection of two discontinuity planes, that is, wedge line (*see* Table 5).

Table 5 LHEF Rating for Structure Showing Relationship between Discontinuity and Slope

[*Clause* 4.2.2(a)]

Sl No.	Condition	Ratings	Total Rating of all Conditions
(1)	(2)	(3)	(4)
i)	Parallelism between slope and discontinuity	0.5	2.0 (0.5 + 1.0 + 0.5)
ii)	Relationship between slope inclination and dip of discontinuity plane/ plunge of wedge line	1.0	
iii)	Dip of discontinuity/ plunge of wedge line	0.5	

Individual conditions are described below along with their LHEF rating ranges.

1) *Parallelism between the slope and the discontinuity* — The extent of parallelism between inclination direction of slope (α_s) and the dip direction of discontinuity plane (α_j) or the plunge direction of line of intersection of two such planes (α_i) is considered here. With increasing amount parallelism, the probability of failure increases (*see* Fig. 1). In LHEF rating scheme, maximum rating given for this condition is 0.50 (*see* Table 6). The symbols and abbreviations (slope condition) used in Tables 6 to 8 for structural ratings has been indicated below:

α_j = dip direction of discontinuity,

α_i = direction of plunge of the line of intersection of two discontinuity surfaces (wedge line),

α_s = direction of slope inclination, β_j = Dip amount of discontinuity,

β_i = amount of plunge of line of intersection of two discontinuity surfaces (wedge line),

β_s = amount of slope inclination,

V F = very favourable,

F = favourable,

U = unfavourable, and

V U = very unfavourable.

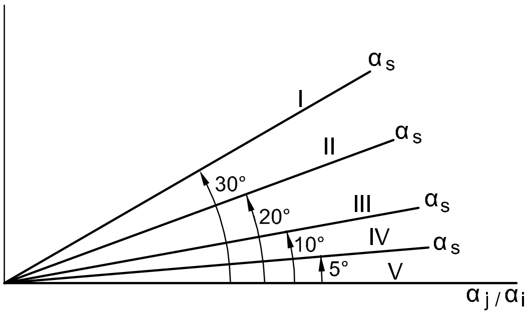


FIG. 1 RELATIONSHIP OF PARALLELISM BETWEEN ORIENTATION OF SLOPE AND DISCONTINUITY

Table 6 LHEF Ratings for Relationship of Parallelism between Slope and Discontinuity

[*Clauses* 4.2.2(a)(1) *and* 4.2.2(b)]

Category	Difference in Angle of Parallelism **a) Translational Failure:** **1. Plane :** $|(\alpha_j - \alpha_s)|$ **2. Wedge :** $|(\alpha_i - \alpha_s)|$ **b) Toppling Failure:** **1. Block Topple:** $|(\alpha_j - \alpha_s) \pm 180°|$ **or** $|(\alpha_j - \alpha_s)|$ **2. Wedge Topple:** $|(\alpha_j - \alpha_s) \pm 180°|$ **or** $|(\alpha_j - \alpha_s)|$	Rating	Slope Condition
(1)	(2)	(3)	(4)
I	> 30°	*0.20*	V F
II	21 - 30°	*0.25*	F
III	11 - 20°	*0.30*	Fair
IV	6 - 10°	*0.40*	U
V	≤ 5°	*0.50*	V U

NOTE — For slopes falling in Category I in Table 6, the ratings for structure as awarded in Tables 7 and 8 will not be applicable and hence a rating of 0 may be awarded out of remaining 1.5 points.

2) *Relationship between slope inclination and dip of discontinuity/plunge of wedge line* — The differences in dip amount of slope and discontinuity plane or plunge of line of intersection of two such planes (wedge line) are taken into consideration. If the slope angle (β_s) is steeper than the dip amount of discontinuity surface (β_j) or plunge of wedge line (β_i), it satisfies condition of day lighting of discontinuity on slope face and it becomes vulnerable to plane or wedge failure modes (*see* Fig. 2). For toppling failure, the dip of the discontinuity is added to inclination amount of the slope. Most unfavourable situation for toppling failure appears when the added value exceeds 160° (*see* Fig. 3). The maximum rating for all these cases are given as 1.00 (*see* Table 7).

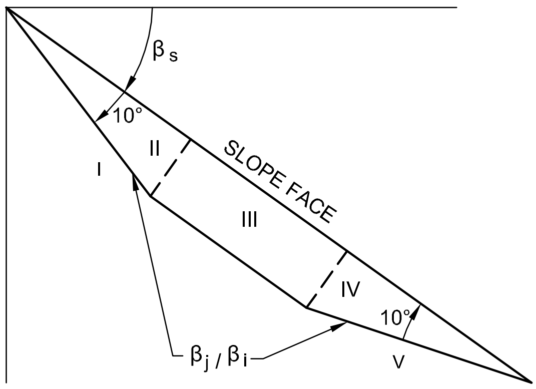
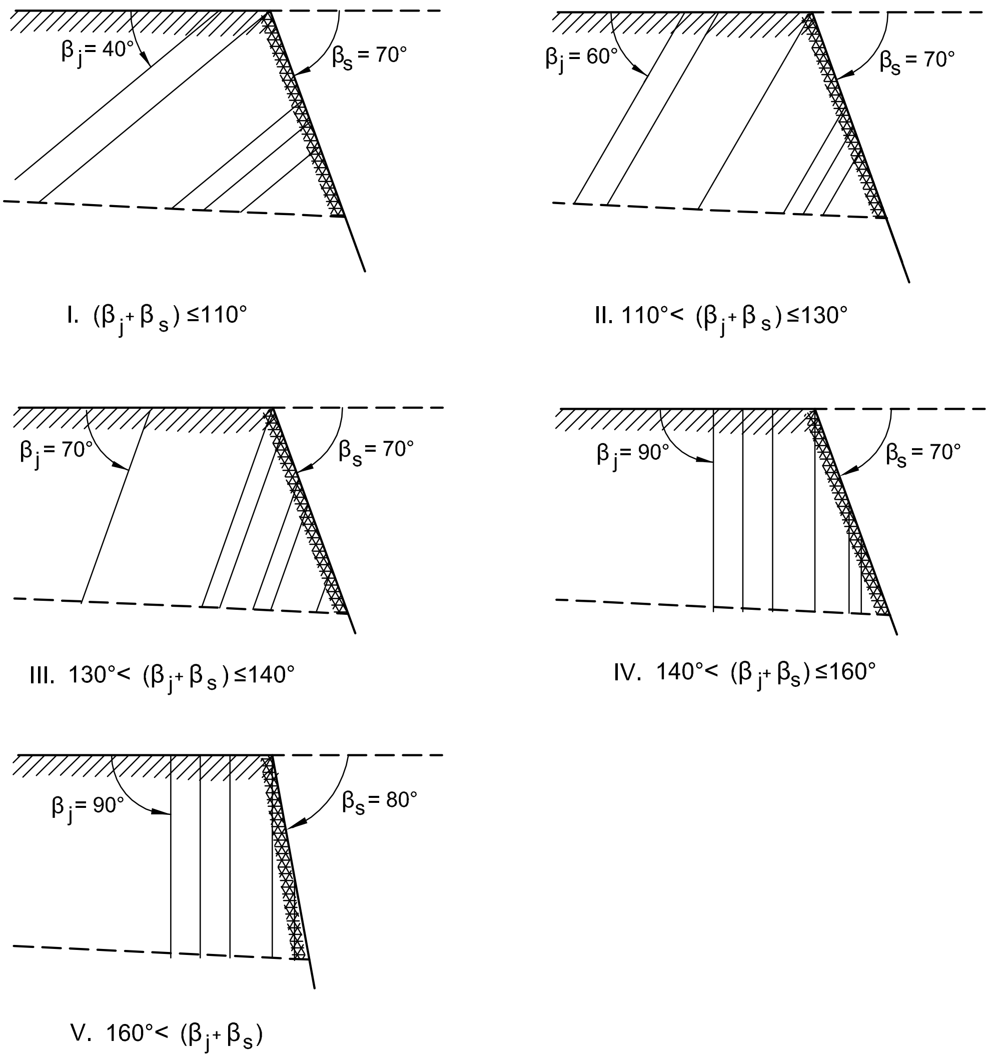


Fig. 2 Relationship Between Slope Angle (β_s) and Dip Amount of Discontinuity (β_j) or Plunge Amount of Wedge Line (β_i) for Plane and Wedge Failure Modes, Respectively. Condition of 'Day Lighting' is Satisfied for Category IV and V.



I. $(\beta_j + \beta_s) \leq 110°$

II. $110° < (\beta_j + \beta_s) \leq 130°$

III. $130° < (\beta_j + \beta_s) \leq 140°$

IV. $140° < (\beta_j + \beta_s) \leq 160°$

V. $160° < (\beta_j + \beta_s)$

Fig. 3 Relationship Between Slope Angle (β_s) and Dip Amount of Discontinuity (β_j) for Block Toppling Failure. Replace β_j with β_i for the Case Wedge Toppling Failure.

Table 7 LHEF Ratings for Relationship Between Amount of Dip of Discontinuity/Plunge of Wedge Line and that of Slope

[*Clauses* 4.2.2(a)(1), 4.2.2(a)(2) *and* 4.2.2(b)]

Sl No.	Category	Difference in Angles a) Plane Failure: $(\beta_j - \beta_s)$ b) Wedge Failure: $(\beta_i - \beta_s)$	Ratings	Sum of Angles a) Block Topple $(\beta_j + \beta_s)$ b) Wedge Topple $(\beta_i + \beta_s)$	Rating	Slope Condition
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	I	> 10°	*0.30*	≤ 110°	*0.30*	V F
ii)	II	0 - 10°	*0.50*	111 - 130°	*0.50*	F
iii)	III	0°	*0.70*	131 - 140°	*0.70*	Fair
iv)	IV	0 – (-10°)	*0.80*	141 - 160°	*0.90*	U
v)	V	> -10°	*1.00*	>160°	*1.00*	V U

NOTE — For slopes falling in Category I in Table 7, the ratings for structure as awarded in Table 8 will not be applicable and hence a rating of 0 may be awarded out of remaining 0.5 points.

3) *Dip of discontinuity/plunge of wedge line* — With increasing the amount of dip of the discontinuity plane (β_j) or the amount of plunge of the line of intersection of two such planes, that is wedge line (β_i), the material may cross angle of friction (Φ) of the rock mass constituting the slope leading to its instability. Steeper the dip/plunge angle, more is the chance of slope failure (*see* Fig. 4). The maximum rating for this relation, as awarded in the rating scheme, is 0.50 (*see* Table 8).

   After determining the ratings of each of the three conditions for individual facets, these are added and based on their respective rating out of 2.0 (maximum LHEF rating for structure), five classes of structure can be determined (*see* Table 9) for every facet. Since, in rock slopes, geological structure plays an important role in inducing instability, this classification will be helpful to identify facets on the final LHZ map which may show high probability of instability with respect to translational and/or toppling failure modes.

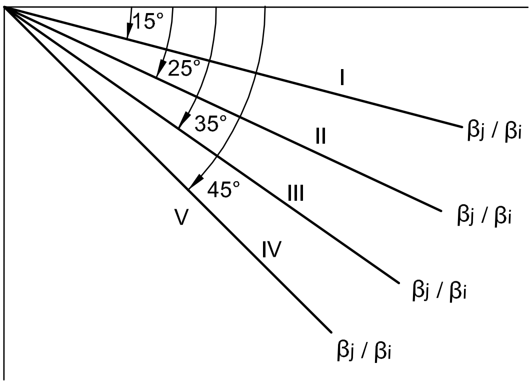


FIG. 4 AMOUNT OF DIP OF DISCONTINUITY FOR INDUCING PLANE AND WEDGE FAILURE WITH CORRESPONDING CATEGORIES

Table 8 LHEF Ratings for Amount of Dip of Discontinuity/Plunge of Wedge Line

[(*Clauses* 4.2.2(a)(1), 4.2.2(a)(3) *and* 4.2.2(b)]

Sl No.	Category	Dip Amount (Plane β_j) Plunge Amount (Wedge β_i)	Ratings	Dip Amount (Block Topple β_j) Plunge Amount (Wedge Topple β_i)	Rating	Slope Condition
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	I	< 15°	*0.20*	< 50°	*0.20*	V F
ii)	II	16 - 25°	*0.25*	51 - 60°	*0.30*	F
iii)	III	26 - 35°	*0.30*	61 - 70°	*0.40*	Fair
iv)	IV	36 - 45°	*0.40*	71 - 80°	*0.45*	U
v)	V	> 45°	*0.50*	> 80°	*0.50*	V U

4) *Effect of major fault, thrust, shear/crushed zones* — In mountainous terrain, particularly in Himalayan condition, encountering major fault, thrust or shear is common on ground and because of extensive crushing of rocks, sometimes it may not be possible to decipher the unfavourable discontinuity plane, as well as its relation with slope orientation. Under these circumstances, it may be advised to demarcate separately, the extent of the crushed/fractured zone on slope facet/facets and keeping in mind the higher possibility of landslide occurrence (depending upon intensity of fracturing), LHEF rating of 2.0 may be awarded.

b) *Soil slopes* — In case of slope facets comprising overburden soil and debris material, geological discontinuities like joints are not observed. In these slopes, the usual mode of failure is in the form of planar debris slide occurring at the contact of the debris/rock (talus failure) and rotational (slip-circular). The type of failure, which may occur, will primarily depend on slope angle, thickness of debris material and other parameters. When slope angle is steep (greater than 35°), it shows more proneness to failure, that is with steeper slope angle, hazard character of slope increases proportionately (*see* Table 10), irrespective of mode of failure. When slope angle is less than 35°, thickness of debris material should be considered to assign the rating (*see* Table 10), as this may also indicate the probable mode of failure (*see* Fig. 5 and *see* Table 10). It has been observed that natural slopes sometimes consist of both *in-situ* rock and overburden materials. For awarding rating for structure in case of a rock slope (*see* Fig 5A), Table 6 to Table 8 may be referred. When slopes are represented by *in-situ* rock with thin (< 5m) overburden cover (*see* Fig. 5B) or with intermittent outcrop of *in-situ* rock for otherwise a debris (colluvial material) slope (*see* Fig. 5C) the mode of failure is dominantly planar debris/talus type. When there is a very thick overburden cover, slip-circular failure is usually expected (*see* Fig. 5D). It is usually observed that for soil slopes, as the depth of overburden soil cover increases on slope facet, the mode of failure gradually changes from talus to circular type (*see* Table 10). The selection of a particular failure mode should be based on geological judgment after proper field check incorporating other parameters like nature of overburden and overall slope angle.

Table 9 Structure Class and Description of Slope Facets Based on their LHEF Ratings

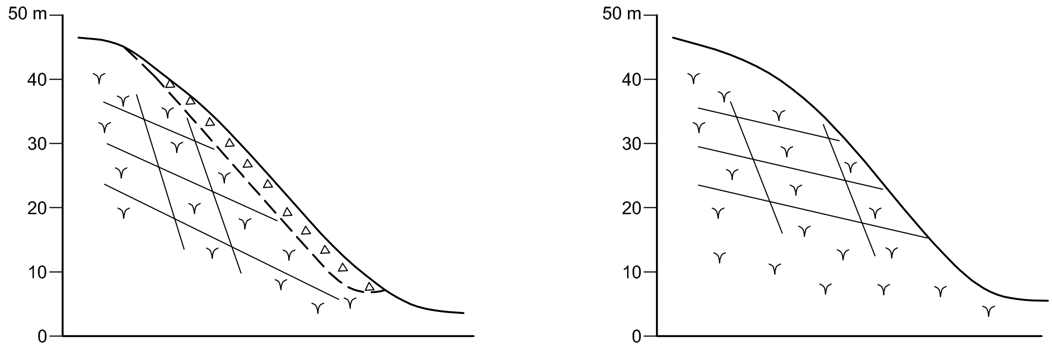
[(*Clause* 4.2.2(a)(1) *and* 4.2.2(a)(3)]

Sl No. (1)	Structure Class (2)	LHEF Rating (Out of 2) (3)	Description (4)
i)	I	LHEF rating ≤ 0.7	Very Favourable
ii)	II	0.7 < LHEF Rating ≤ 1.05	Favourable
iii)	III	1.05 < LHEF Rating ≤ 1.4	Fair
iv)	IV	1.4 < LHEF Rating ≤ 1.75	Unfavourable
v)	V	LHEF Rating > 1.75	Very Unfavourable

Table 10 LHEF Ratings for Structure Category in Loose Soil/Debris Slope

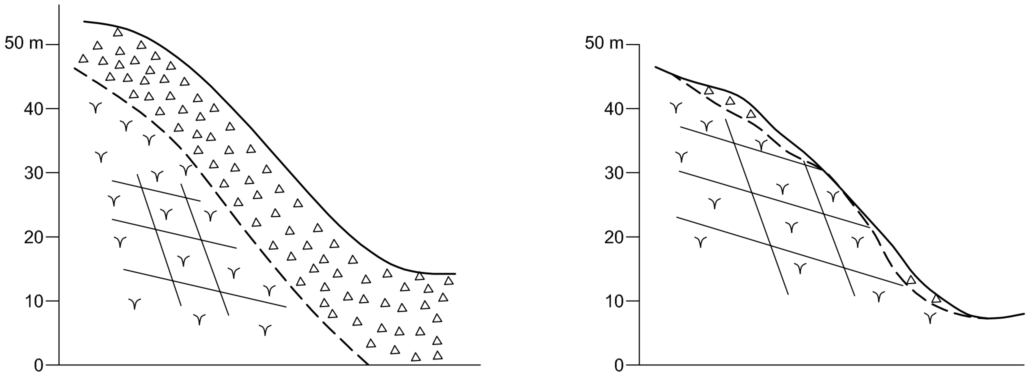
[*Clause* 4.2.2(b)]

A. Slope Angle > 35°; slope angle is the criteria for Awarding LHEF Rating		
Slope Angle	**Probable Mode of Failure**	**Rating**
36 - 45º	Probability of slope instability increases with increasing slope angle, whatever be the failure mode	1.0
46 - 60º		1.5
> 60º		2.0
B. Slope Angle ≤ 35°; thickness of Overburden is the Criteria for Awarding LHEF Rating		
Overburden Thickness	**Probable Mode of Failure**	**Rating**
< 5m	Dominantly planar debris slide (talus slide)	0.65
5 – 10m	Planar debris slide and sometimes rotational slide	0.85
11 – 15m	Rotational slide and sometimes planar debris slide	1.30
16 – 20m	Dominantly rotational slide (circular failure), though some times slip circle may be non-circular type	1.50
> 20m		2.00



5A ROCK SLOPE COVER

5B ROCK SLOPE WITH THIN OVERBURDEN



5C ROCK SLOPE WITH INTERMITTENT OCCURRENCE OF OVERBURDEN

5D THICK OVERBURDEN COVER OF SOIL AND DEBRIS OVER ROCK

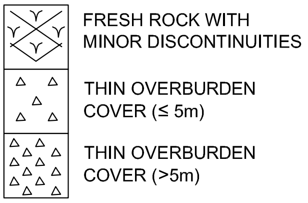

FRESH ROCK WITH MINOR DISCONTINUITIES
THIN OVERBURDEN COVER (≤ 5m)
THIN OVERBURDEN COVER (>5m)

FIG. 5 VARIOUS FIELD CONDITIONS OF SOIL AND OVERBURDEN COVER SEEN ON ROCK SLOPES

4.2.3 *Slope Parameter*

Slope parameter includes the effect of slope morphometry (slope angle) and relative relief of individual facets. In meso-zonation approach, the impact of these two factors have been considered together to assess their significance in inducing instability. In this context, it is proposed to consider their combined significance in a matrix form, which is shown in Table 13. The maximum LHEF rating for slope parameter is 2.0. Brief description of these two factors that is, slope morphometry and relative relief, are given below:

a) *Slope morphometry* — Slope morphometry map categories facets based on inclination angle of slopes. For this purpose topographic maps in appropriate scale (1 : 5 000 – 1 : 10 000) are also required. The slope morphometry maps for meso-zonation purpose are prepared after getting the slope angle from sections drawn through slope facet along the direction of inclination incorporating the highest and lowest contours passing through the facet. For meso-zonation purpose, an equal spacing of contours may not be available due to minor variation of slope angles including local steep slopes. Hence an average slope angle for the whole facet is judiciously selected. If there is a significant variation (greater than 20°) along the slope profile for a considerable part, it is better to study that local slope making a separate facet or sub-facet. Slope angles, with certain range, are divided into six different classes (Class A to Class F) which are presented in Table 11 along with probable failure modes.

b) *Relative relief* — Relative relief represents the maximum height of a slope facet, from top (like ridge/spur) to bottom (like valley floor), in the direction of slope inclination. Relief of a facet can simply be calculated by counting the elevation difference between the lowest and the highest elevations (following contours) along the slope direction. For meso-zonation purpose, five relative relief classes (Class I to Class V) has been considered (*see* Table 12).

The combined impact of these two factors has been considered to award LHEF rating for slope parameter. Accordingly a [5×6] matrix format has been prepared on which relative relief classes of slope are shown row wise and slope morphometry classes are presented column wise (*see* Table 13). The LHEF ratings increase considerably while moving along the row (from left to right) than descending down the column. This implies that of the two factors, more importance has been given to slope morphometry than relative relief. This is because the former reflects change in slope gradient which is considered to be more important for selecting a slope for locating urban structures. On the basis of the LHEF rating values, the slope parameter has been further categorized into five classes (Class I to Class V) indicating the suitability of slopes for construction purpose (*see* Table 14). From Table 13 it can be inferred that slopes with steep slope angle (greater than 35°) and high relief (greater than 100 m) are usually not favorable for civil constructions (*see* Table 14), whereas, those slopes with gentle angle and low relief are considered to be very favorable.

4.2.4 *Land Use and Land Cover*

Land use and land cover pattern is one of the important parameters governing slope stability and in LHEF scheme maximum rating of 2.0 has been awarded for this factor. Vegetation has major role to resist slope movements, particularly for failures with shallow slip/rupture surfaces. A well spread network of root system increases the shearing resistance of the slope material due to natural anchoring of slope materials, particularly for soil slopes. Moreover, a thick vegetation or grass cover reduces the action of weathering and erosion, hence adds to stability of the slopes. On the other hand, barren or sparsely vegetated slopes are usually exposed to weathering and erosion action, thus rendering it vulnerable to failure.

In mountainous terrain, chances of landslide occurrence, increases many folds for slopes which face toe erosion/toe cutting by first order streams or fast moving water of any other natural drainages. Agricultural activity is generally practiced on hill slopes which are very gentle to gentle. For higher slope angle, usually it is carried out by making flat terraces. These slopes, apart from receiving natural precipitation, also get recharged by additional water for agriculture purpose. Because of the fact that even after many years of such practice they

Table 11 Slope Morphometry Classes Based on Slope Angle of Facets

[(*Clause* 4.2.3(a)]

Sl No. (1)	Slope Angle (2)	Slope Type (3)	Class (4)	Probable Mode of Failure (5)
i)	< 15°	Very gentle slope	A	Slides with probable creep movement
ii)	16° – 25°	Gentle slope	B	
iii)	26° – 35°	Moderate slope	C	Slides
iv)	36°– 45°	Steep slope	D	
v)	46° – 65°	Very steep slope	E	Slides and falls
vi)	> 65°	Escarpment / Cliff	F	Slides, falls, topples and flows

Table 12 Relative Relief Classes Based on Slope Height

[(*Clause* 4.2.3(b)]

Sl No. (1)	Slope Height m (2)	Class (3)	Description (4)
i)	< 50	I	Very low relief
ii)	50 - 100	II	Low relief
iii)	101 - 200	III	Medium relief
iv)	201 - 300	IV	High relief
v)	> 300	V	Very high relief

Table 13 LHEF Rating for Slope Parameter Classes

[*Clause* 4.2.3(b)]

LHEF Ratings for Slope Parameter		Slope Morphometry Classes					
		A (<15°)	B (16°–`25°)	C (26°–35°)	D (36°–45°)	E (46°–65°)	F (>65°)
Relative Relief Classes	I (<50 m)	0.5	0.9	1.3	1.5	1.8	1.9
	II (50 -100 m)	0.6	1.0	1.4	1.6	1.9	2.0
	III (101-200 m)	0.7	1.1	1.5	1.7	1.95	2.0
	IV (201-300 m)	0.8	1.2	1.55	1.75	2.0	2.0
	V (>300 m)	0.9	1.3	1.6	1.8	2.0	2.0

Table 14 Slope Parameter Class Based on LHEF Ratings of the Same

(*Clause* 4.2.3)

Sl No. (1)	LHEF Ratings for Slope Parameter (2)	Description (3)	Class (4)
i)	LHEF Rating < 0.8	Very favourable	I
ii)	0.8 < LHEF Rating ≤ 1.2	Favorable	II
iii)	1.2 < LHEF Rating ≤ 1.6	Moderately favorable	III
iv)	1.6 < LHEF Rating ≤ 1.8	Unfavorable	IV
v)	LHEF Rating > 1.8	Very unfavorable	V

remain stable, it is quite logical to consider them as safe from landslide point of view. Similarly, a populated land on a very gentle slope (slope angle ≤ 15°) under normal circumstances is least expected to suffer from slope instability.

Slope instability is also induced because of anthropogenic activities, that is urbanization, particularly on higher slope angles (≥ 30°). It not only removes vegetation cover but also adds to the natural weight of the slope as surcharge due to weight of civil structures. In a hill slope with higher slope angle, buildings are usually located by making local cut slopes and flat terraces. With this concept urbanization is broadly classified into three categories. A sparsely urbanized slope is one where terraces are located far apart (more than 15 m of horizontal spacing) providing a considerable distance between two terraces along the slope. A moderately urbanized slope is characterized by comparatively closer location of construction terraces but leaving an optimal horizontal spacing of 5-15 m between individual terraces. In a heavily urbanized slope construction terraces are located very close to each other (≤ 5m horizontal spacing) in such a way that successive terraces almost touch each other at places. With increasing urbanization, water due to domestic usage may be released on the slope surface wherever the drainage measure is inadequate. This water may get added up to the sub-surface water and may develop pore water pressure, leading to slope instability. Similarly barren land, affected by anthropogenic activities has also been found to be most vulnerable to landslides. All these aspects have been suitably accounted while awarding the LHEF ratings (*see* Table 15).

Table 15 Ratings for Land Use and Land Cover Types

(*Clause* 4.2.4)

Sl No. (1)	Land Use and Land Cover Types (2)	Rating (3)
i)	Agricultural land or populated flat land (≤ 15°)	0.65
ii)	Thickly vegetated forest area	0.80
iii)	Moderately vegetated forest area	1.20
iv)	Sparsely vegetated area with thin grass cover	1.50
v)	Barren land without anthropogenic activity	1.70
vi)	Hill slopes experiencing active toe erosion/toe cutting by rivers, streams or any other form of natural drainage	2.00
vii)	Sparsely urbanized slope	1.20
viii)	Moderately urbanized slope	1.50
ix)	Heavily urbanized slope:	
	a) With proper surface and subsurface drainage measures – no wet patches on slope	1.60
	b) Inadequate drainage measures – dampness or wet patches left on slope	1.80
x)	Barren land with slope excavation (cut slopes for rail and road routes, construction terraces, mining activities, etc) incurring deficient blasting and induced vibration damage to slope	2.00

4.2.5 *Hydrogeological Conditions*

The hydrogeological conditions are studied based on visual estimation of groundwater condition on slope surface using relative qualitative terms such as dry, damp, wet, dripping and flowing. Presence of water generally decreases the shear strength of the slope forming material and thereby increasing the probability of slope failure. Since it is difficult to assess sub-surface flow of groundwater quantitatively for the entire facet, visual estimation of field conditions has been considered as an alternative measure to award the ratings. For better representative assessment of groundwater condition, it is advisable to collect field data during post-monsoon period. Maximum rating for this parameter is 1.0 and field hydrogeological conditions of facets along with their respective ratings have been tabulated in Table 16.

Table 16 LHEF Ratings for Hydrogeological Conditions

(*Clause* 4.2.5)

Sl No.	Hydrogeological Conditions as Observed on Facet	Ratings
(1)	(2)	(3)
i)	Flowing	1.0
ii)	Dripping	0.8
iii)	Wet	0.5
iv)	Damp	0.2
v)	Dry	0.0

4.2.6 *External Factors (Seismicity and Rainfall)*

External causative factors like seismicity and rainfall may initiate slope movement and are accordingly called as triggering factors. Seismicity and rainfall pattern usually remain same or with minor variation for a large area (regional factors) and for meso-zonation purpose it is obvious that their effect will not vary from facet to facet. But the location of study area is important keeping in view of regional seismicity and rainfall pattern. Seismically, India is divided into four major seismic zones, from Zone II to Zone V [*see* IS 1893 (Part 1)] on the basis of intensity of ground motion which increases proportionately from Zone II to Zone V. In Zone II, the ground motion is least for which it represents an area of minimum seismic hazard while Zone V indicates an area of maximum intensity of ground motion, that is, most prone to seismic hazards. So a slope which is critically stable under existing slope conditions may become unstable if it falls in higher seismic zones and may result into landslide. Hill slopes falling in zones of high annual precipitation are also prone to landslide activities. Following a heavy spell of rain there is always chances of sudden pore water pressure built up in these slopes and this may also induce slope instability. The rainfall distribution map of India is taken as input data to award the LHEF ratings. These points are taken into consideration while awarding ratings for external parameters. It is obvious, if a hill slope fall in high annual precipitation zone which is also seismically active (as in the case of Himalaya), the probability of slope failure also increases. The maximum rating for external parameter is 1.0 which is divided equally to award ratings for seismicity and rainfall (*see* Table 17). Ratings for these two factors shall be given separately and finally added to the LHEF ratings for inherent parameters to assess the overall hazard potential of the slope. The description of subcategories and their corresponding ratings are indicated in Table 17.

Table 17 LHEF Rating for External Factors

(*Clause* 4.2.6)

Sl No.	Seismic Zone	Ratings	Average Annual Rainfall of the Area	Rating
(1)	(2)	(3)	(4)	(5)
i)	II	0.2	≤ 50 cm	0.2
ii)	III	0.3	51 – 100 cm	0.3
iii)	IV	0.4	101 – 150 cm	0.4
iv)	V	0.5	> 150 cm or history of cloud burst	0.5

5 CALCULATION OF TOTAL ESTIMATED HAZARD (TEHD) VALUE OF SLOPE FACETS FROM LHEF RATING

Total estimated hazard (TEHD) indicates the overall condition of instability and shall be calculated facetwise by adding the LHEF ratings of all five inherent parameters along with the external parameters, that is seismicity and rainfall. The final value of LHEF, thus obtained on 10 point scale, is called TEHD value, which can vary widely from one facet to another depending on the condition of instability of the respective facets.

Total Estimated Hazard (TEHD) value = LHEF Ratings for [Inherent factors {lithology + structure + slope parameter (slope morphometry and relative relief) + land use and land cover + hydrogeological conditions} + External factors {seismicity and rainfall}]

The LHZ map on meso-scale of an area is prepared from the TEHD values of the facets. On the basis of range of TEHD values, five categories of relative hazard classes can be assigned (*see* Table 18).

Table 18 Landslide Hazard Zones Based on Total Estimated Hazard Values

(*Clause* 5)

Sl No. (1)	Landslide Hazard Zone (2)	Range of TEHD Value (3)	Description of Zone (4)
i)	I	TEHD < 3.5	Very Low Hazard (VLH) zone
ii)	II	3.5 ≤ TEHD < 5.0	Low Hazard (LH) zone
iii)	III	5.0 ≤ TEHD ≤ 6.5	Moderate Hazard (MH) zone
iv)	IV	6.5 < TEHD ≤ 8.0	High Hazard (HH) zone
v)	V	TEHD > 8.0	Very High Hazard (VHH) zone

6 PROCEDURE FOR LHZ MAPPING ON MESO SCALE

6.1 The LHZ mapping on meso-scale is an empirical approach which involves hazard assessment of hill slopes and is carried out in two phases, namely desk study, and field study.

The procedure of preparing the map is shown in the form of a flow chart (*see* Fig. 6).

a) *Desk study* — Initially toposheets, geological maps, aerial photographs and satellite imageries on 1 : 5 000 to 1 : 10 000 scale are acquired. The meso-scale LHZ study starts with the preparation of slope facet map (which serves the purpose of base map) mainly from toposheets. Later, various pre-field thematic maps are prepared using LHEF rating scheme using slope facet map as the base. For that purpose, important topographic features are to be identified before field visit. Apart from topographic map, aerial photographs and satellite imageries in appropriate scale are also studied to prepare slope facet map of the study area. In fact, the slope facets can be numbered and other required data collected in a tabulated form in addition to preparing thematic maps.

   Pre-field slope morphometry and relative relief maps can be prepared mainly from topographic map in addition to using relevant inputs from aerial photographs and satellite imageries. Taking these two maps as inputs, pre-field slope parameter map of the area can easily be prepared. Pre-field geological maps consisting of lithological and structural maps are prepared separately on the required scale of 1 : 5 000 to 1 : 10 000. If not available, regional geological maps of the area can be referred and required details can be transferred to meso-scale. Pre-field land use and land cover map and hydrogeological map can be prepared from toposheets, aerial photographs and satellite imageries. The data derived from all these maps are called pre-field data and the maps are called pre-field thematic maps. Hence, during desk study, all the factorial thematic maps shall be prepared on the slope facet map, which can be carried to the field for further verification and modification. Information gathered from desk study will help to plan and execute field study in a systematic manner.

b) *Field study* — During field visit all the pre-field maps are verified facet wise and necessary corrections shall be done, based on field study. This process will upgrade the existing pre-field maps. Once the data related to six parameters are upgraded after field study, their ratings can be awarded as per the LHEF rating scheme and the pre-field thematic maps are finalized. After finalizing the LHEF ratings for inherent factors, correction rating for external factors (seismicity and rainfall) shall be assigned to slope facets.

6.2 In order to obtain total estimated hazard (TEHD) value, the LHEF ratings of inherent and external parameters are added. The value of TEHD indicates overall hazard probability and shall be calculated facet wise. It can vary widely from one facet to another depending on the condition of stability of the respective facets. Based on TEHD values the hazard class for each facet can be assigned and this will produce the Meso-Scale LHZ map of the area.

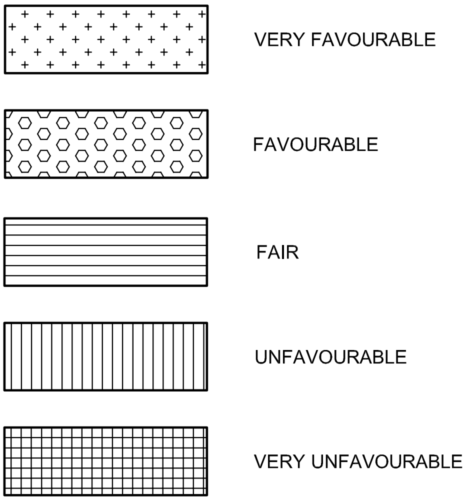
7 PRESENTATION OF RESULTS

7.1 The results shall be presented in the form of maps. The terrain evaluation/factorial/thematic maps shall be prepared in the first stage showing the nature of facet-wise distribution of causative factors. After assigning the LHEF ratings for inherent and external causative factors, the TEHD values for facets can be worked out. The LHZ map on meso-scale of an area shall be prepared from facet wise distribution of TEHD values.

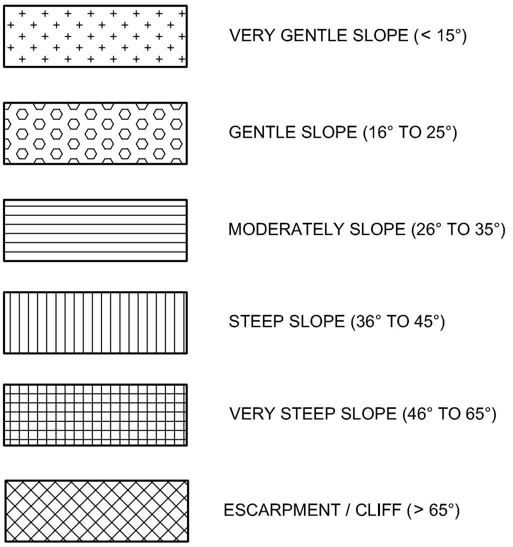
7.2 Symbols for Lithological and Structural Maps

The symbols and abbreviations given in IS 7422 (Part 1), IS 7422 (Part 2), IS 7422 (Part 3), IS 7422 (Part 4) and IS 7422 (Part 5) shall be used for lithological and structural maps.

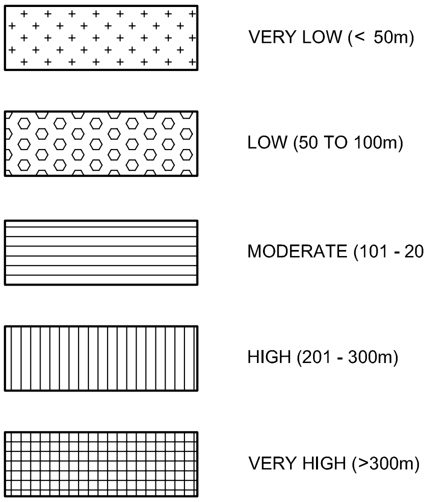
7.3 Suggested Symbols for Structure Class Map



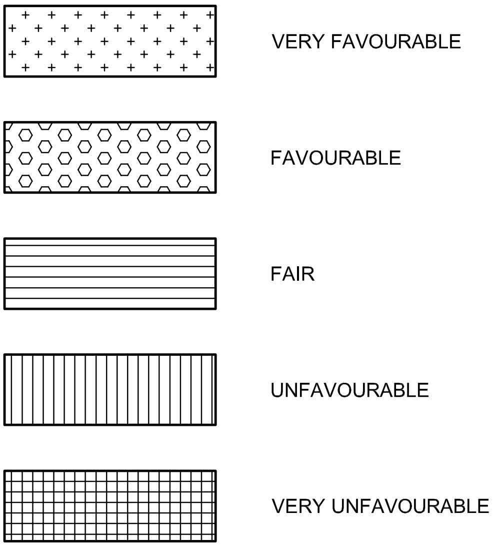
7.4 Suggested Symbols for Slope Morphometry Map


VERY GENTLE SLOPE (< 15°)
GENTLE SLOPE (16° TO 25°)
MODERATELY SLOPE (26° TO 35°)
STEEP SLOPE (36° TO 45°)
VERY STEEP SLOPE (46° TO 65°)
ESCARPMENT / CLIFF (> 65°)

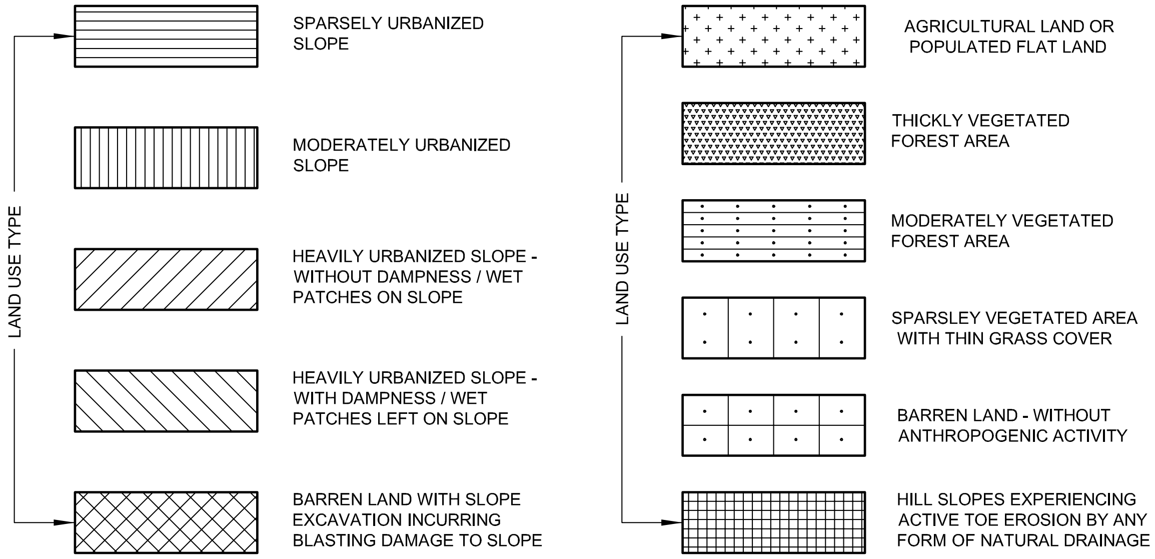
7.5 Suggested Symbols for Relative Relief Map



7.6 Suggested Symbols for Slope Parameter Map



7.7 Suggested Symbols for Land Use and Land Cover Map

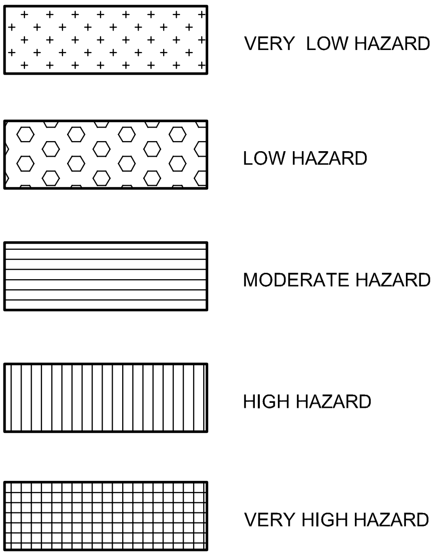

LAND USE TYPE
SPARSELY URBANIZED SLOPE
MODERATELY URBANIZED SLOPE
HEAVILY URBANIZED SLOPE - WITHOUT DAMPNESS / WET PATCHES ON SLOPE
HEAVILY URBANIZED SLOPE - WITH DAMPNESS / WET PATCHES LEFT ON SLOPE
BARREN LAND WITH SLOPE EXCAVATION INCURRING BLASTING DAMAGE TO SLOPE
LAND USE TYPE
AGRICULTURAL LAND OR POPULATED FLAT LAND
THICKLY VEGETATED FOREST AREA
MODERATELY VEGETATED FOREST AREA
SPARSLEY VEGETATED AREA WITH THIN GRASS COVER
BARREN LAND - WITHOUT ANTHROPOGENIC ACTIVITY
HILL SLOPES EXPERIENCING ACTIVE TOE EROSION BY ANY FORM OF NATURAL DRAINAGE

7.8 Suggested Symbols for Map Showing Hydrogeological Condition

The symbols and abbreviations given in IS 14496 (Part 2) shall be used for map for hydrogeological condition.

7.9 Suggested Symbols for Meso-scale LHZ Map

The symbols and abbreviations given in IS 14496 (Part 2) shall be used for preparing LHZ map for meso-zonation purpose.



8 INTERPRETATION OF MESO-SCALE LHZ MAP

For town planning and construction purposes, slope facets which fall in Very Low Hazard (VLH) and Low Hazard (LH) zones are the most suitable. On the other hand, slopes falling in High Hazard (HH) and Very High Hazard (VHH) are usually considered unfavourable and may be avoided as far as possible. In comparison to VHH and HH facets, slopes falling in Moderate Hazard (MH) zone are considered relatively safe for construction practice. But they may contain local areas of instability, which should be suitably taken care, while planning for any construction on these slopes. If constructions are to be carried out in HH and VHH slopes, then suitable studies and control measures should be taken up prior to construction. Preferably these facets shall be studied in detail on 1 : 1 000 - 1 : 2 000 scale incorporating analytical and observational techniques in order to understand status of stability of the concerned slope and plan suitable control measures. Typical thematic maps and meso scale LHZ map have been shown in Fig. 7 to Fig. 16.

9 UTILITY OF MESO-SCALE LHZ MAP

A LHZ map on meso-scale (1 : 5 000 to 1 : 10 000) will show the spatial distribution of hazard zones and accordingly help the town planners to select relatively safe areas for future constructions and development related works in hilly regions, like systematic town planning, expansion of existing urban settlements, setting up of satellite townships and other similar purposes, such as road/railway alignment, tunnel alignment, dam, bridge and planning of high tension power lines. Civil engineers can also get help by this map by either avoiding hazardous zones during planning stage or taking necessary preventative measures, before construction, if hazard zones are unavoidable for locating that structure. These maps will also be useful to plan bye-pass roads for hill towns. The alternate communication routes in case of landslides, flood, fire and other natural hazards can be planned using this map. Further hazard classes, as derived after application of meso-zonation technique on any hill area, may also be used for the purpose of risk assessment on same scale.

10 REVISION OF MESO-SCALE LHZ MAP

The meso-scale LHZ map shall be revised from time to time, especially after natural events like major earthquake (greater than 5 on Richter’s Scale) close to study area, flood, cyclone, prolonged rainfall or cloud burst along with mining and constructional activities on large scale, as these incidences may trigger fresh landslides/slope instabilities in hilly areas.

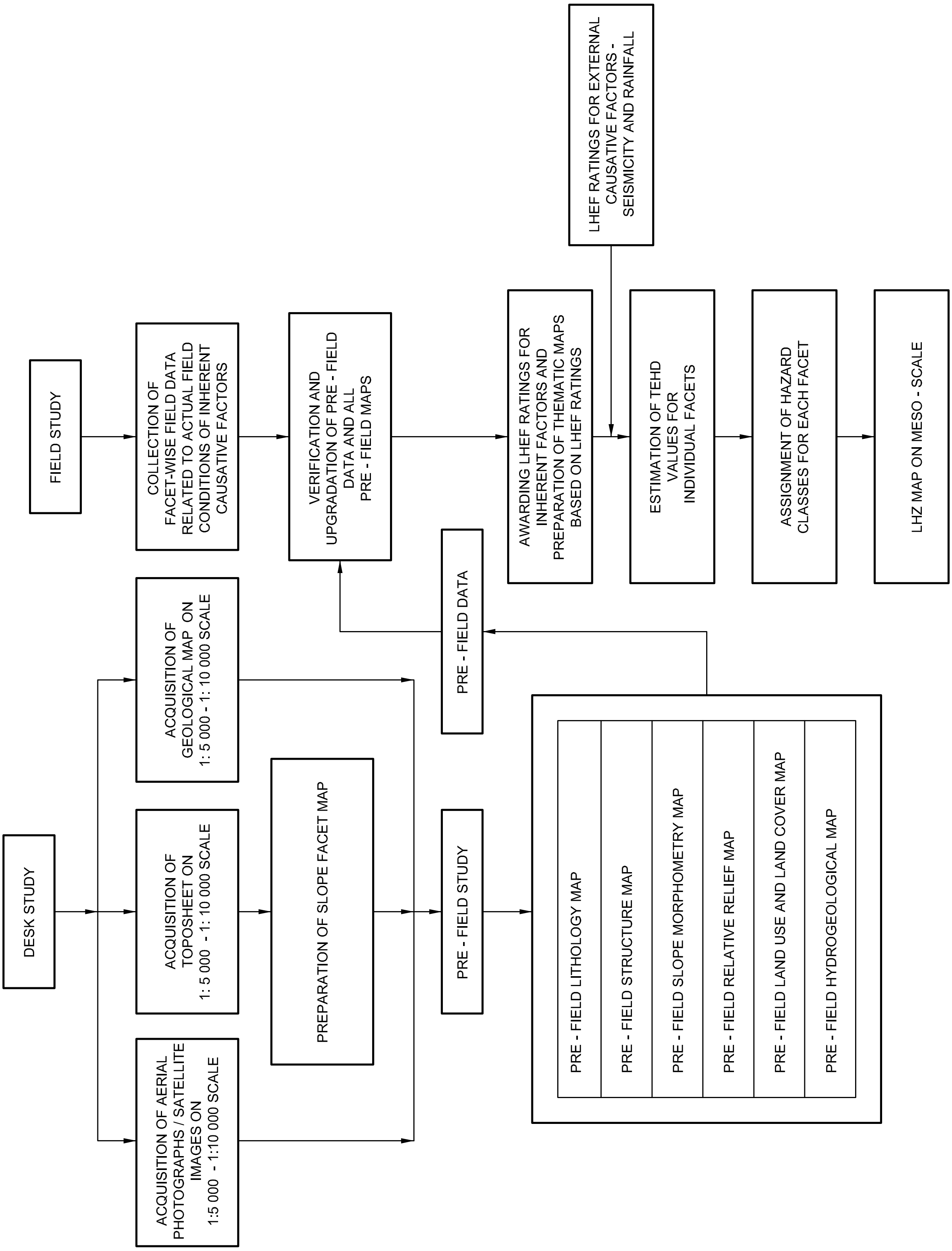

DESK STUDY
ACQUISITION OF AERIAL PHOTOGRAPHS / SATELLITE IMAGES ON 1:5 000 - 1:10 000 SCALE
ACQUISITION OF TOPOSHEET ON 1: 5 000 - 1: 10 000 SCALE
ACQUISITION OF GEOLOGICAL MAP ON 1: 5 000 - 1: 10 000 SCALE
PREPARATION OF SLOPE FACET MAP
PRE - FIELD STUDY
PRE - FIELD LITHOLOGY MAP
PRE - FIELD STRUCTURE MAP
PRE - FIELD SLOPE MORPHOMETRY MAP
PRE - FIELD RELATIVE RELIEF MAP
PRE - FIELD LAND USE AND LAND COVER MAP
PRE - FIELD HYDROGEOLOGICAL MAP
PRE - FIELD DATA
FIELD STUDY
COLLECTION OF FACET-WISE FIELD DATA RELATED TO ACTUAL FIELD CONDITIONS OF INHERENT CAUSATIVE FACTORS
VERIFICATION AND UPGRADATION OF PRE - FIELD DATA AND ALL PRE - FIELD MAPS
AWARDING LHEF RATINGS FOR INHERENT FACTORS AND PREPARATION OF THEMATIC MAPS BASED ON LHEF RATINGS
LHEF RATINGS FOR EXTERNAL CAUSATIVE FACTORS - SEISMICITY AND RAINFALL
ESTIMATION OF TEHD VALUES FOR INDIVIDUAL FACETS
ASSIGNMENT OF HAZARD CLASSES FOR EACH FACET
LHZ MAP ON MESO - SCALE

FIG. 6 FLOW CHART FOR PREPARATION OF LHZ MAP ON MESO-SCALE (1 : 5 000 TO 1 : 10 000)

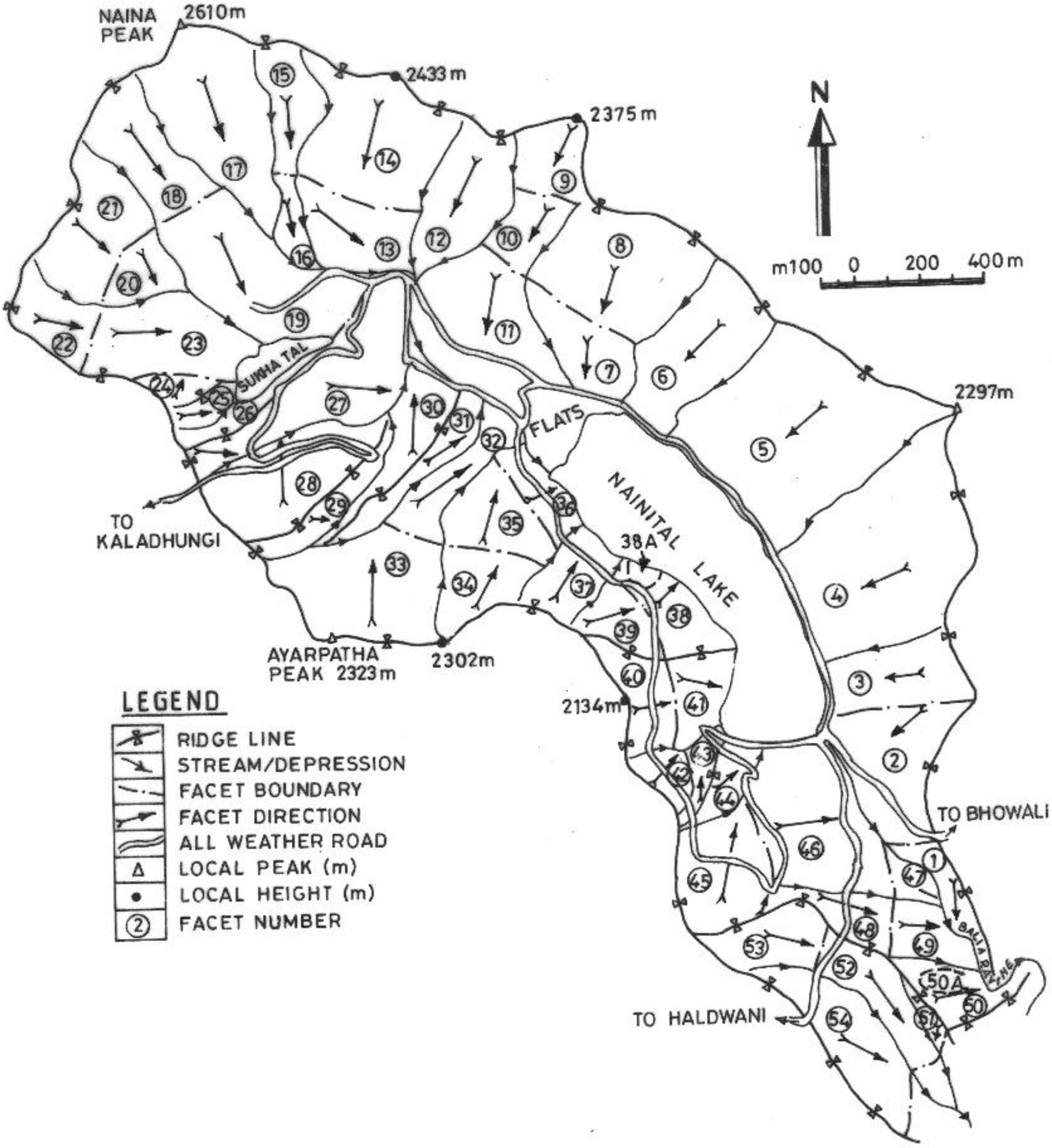


FIG. 7 TYPICAL SLOPE FACET MAP

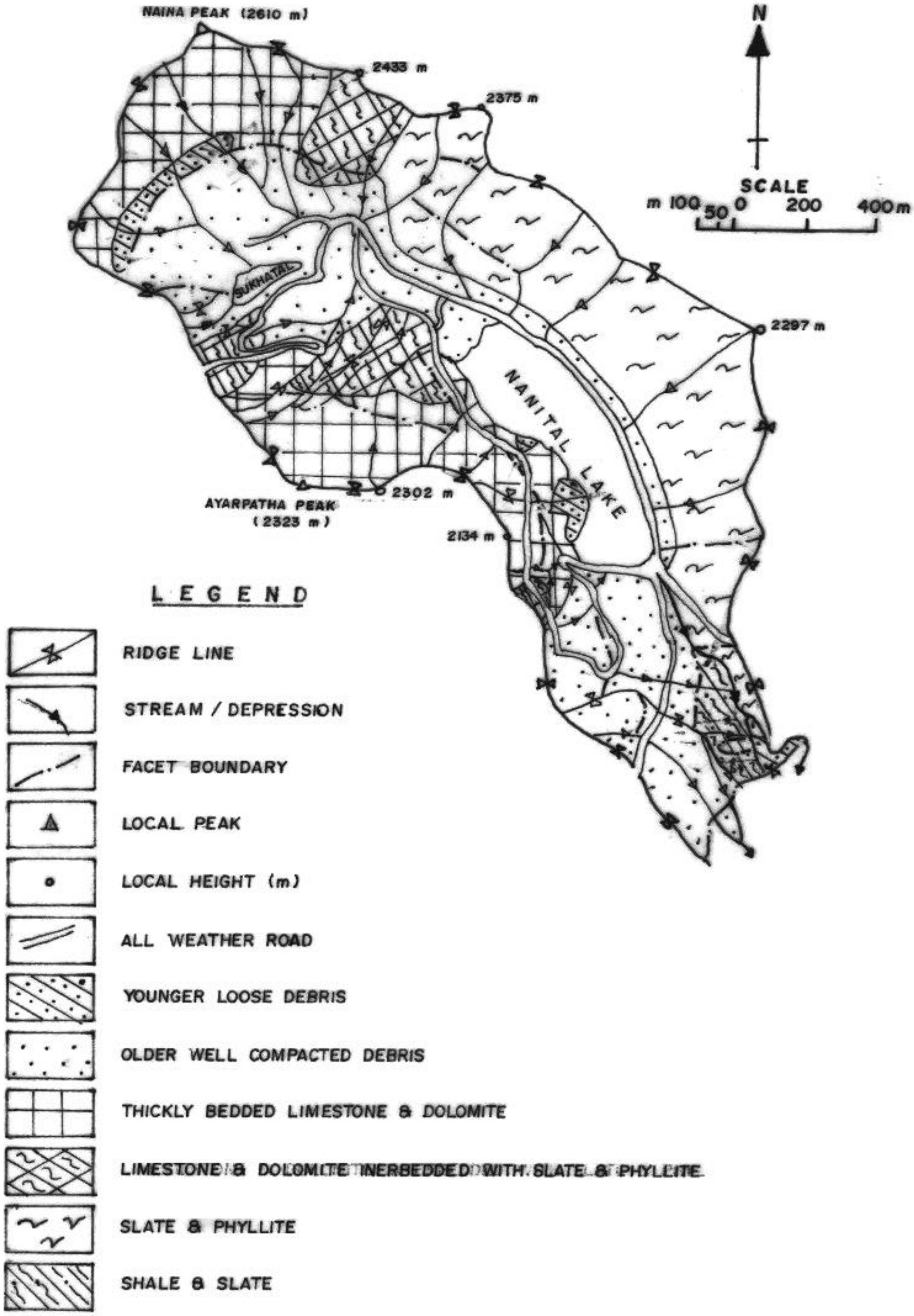


FIG. 8 TYPICAL LITHOLOGY MAP

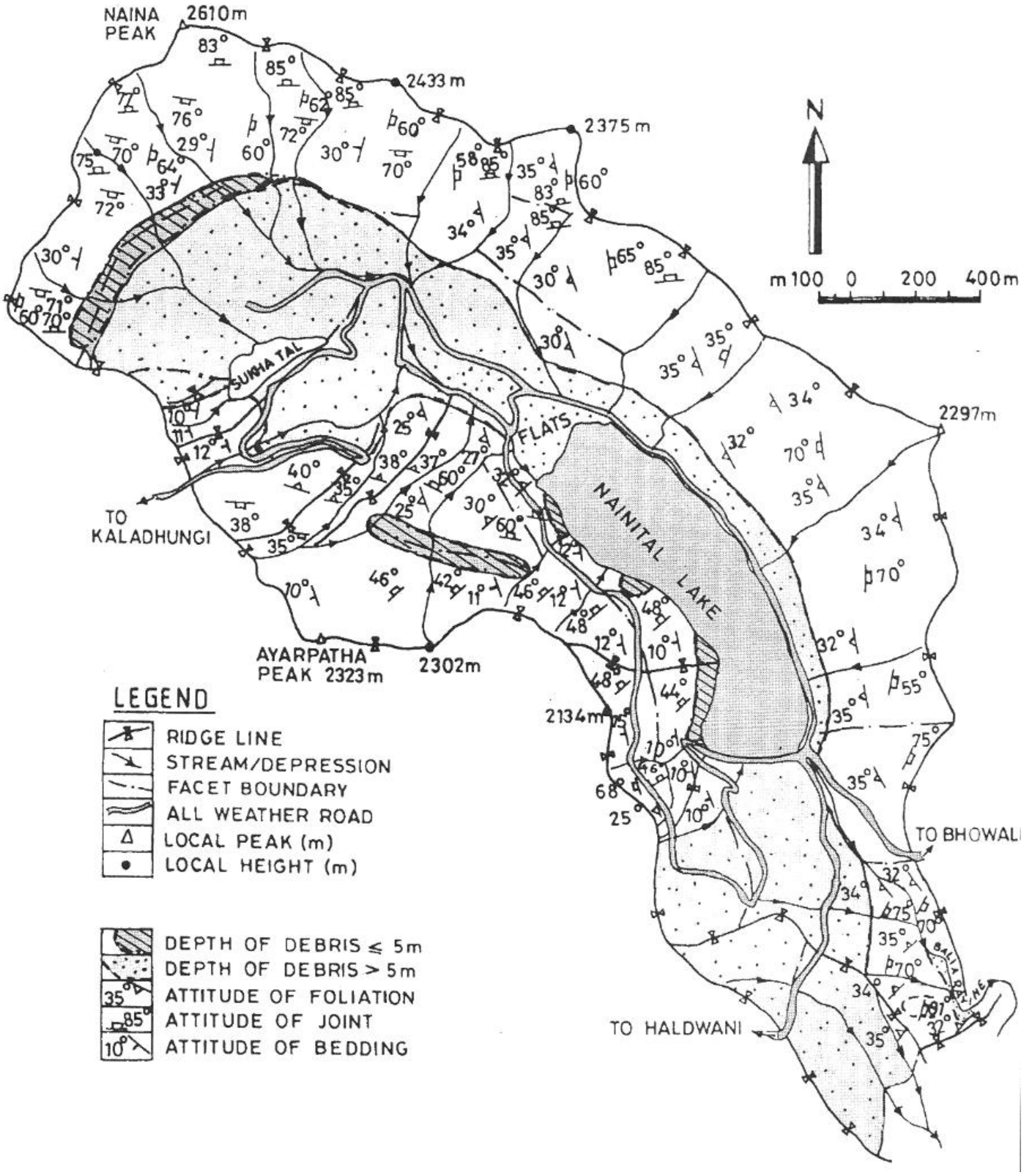


FIG. 9 TYPICAL STRUCTURE MAP

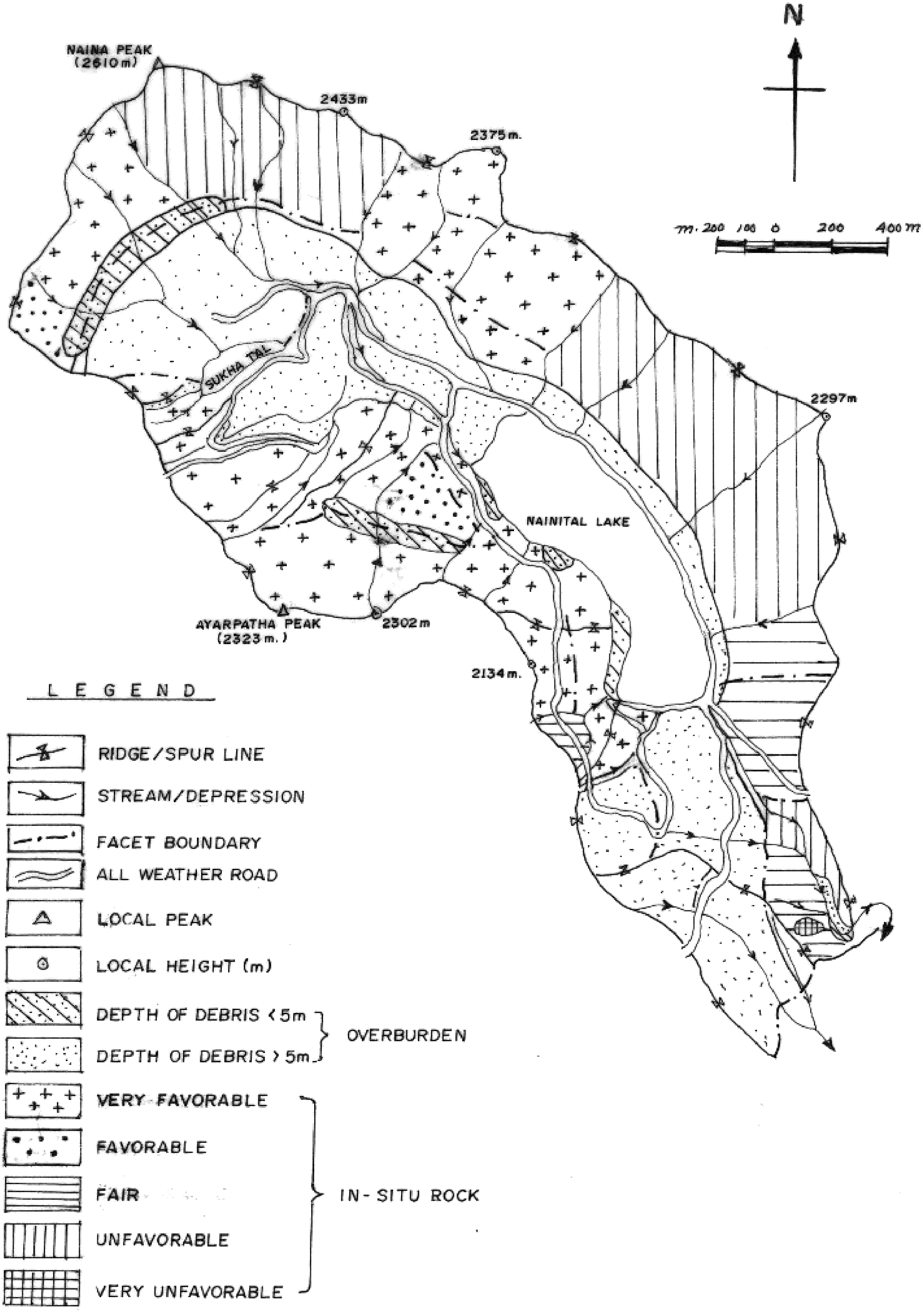


FIG. 10 TYPICAL STRUCTURE CLASS MAP

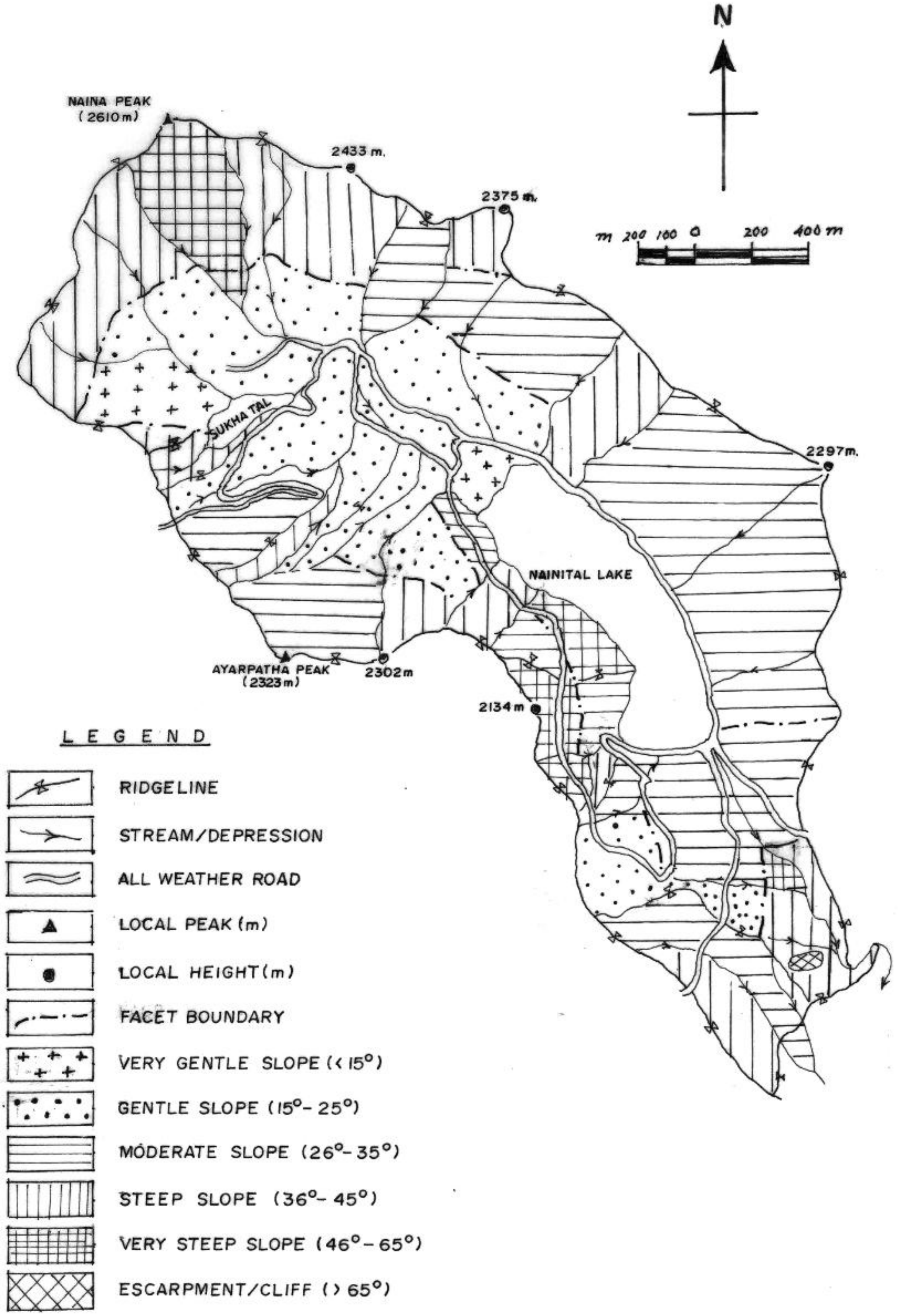


FIG. 11 TYPICAL SLOPE MORPHOMETRY MAP

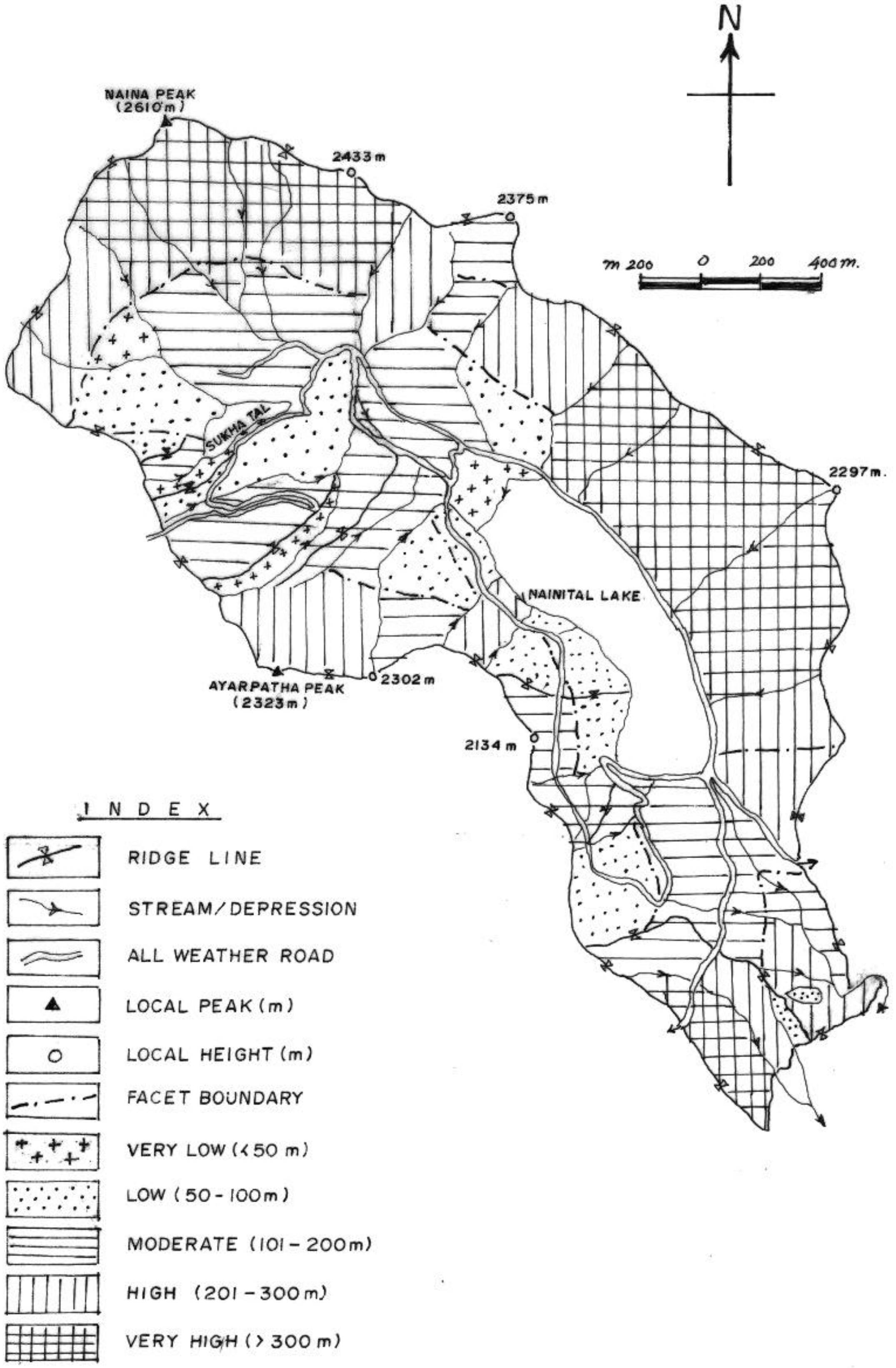


FIG. 12 TYPICAL RELATIVE RELIEF MAP

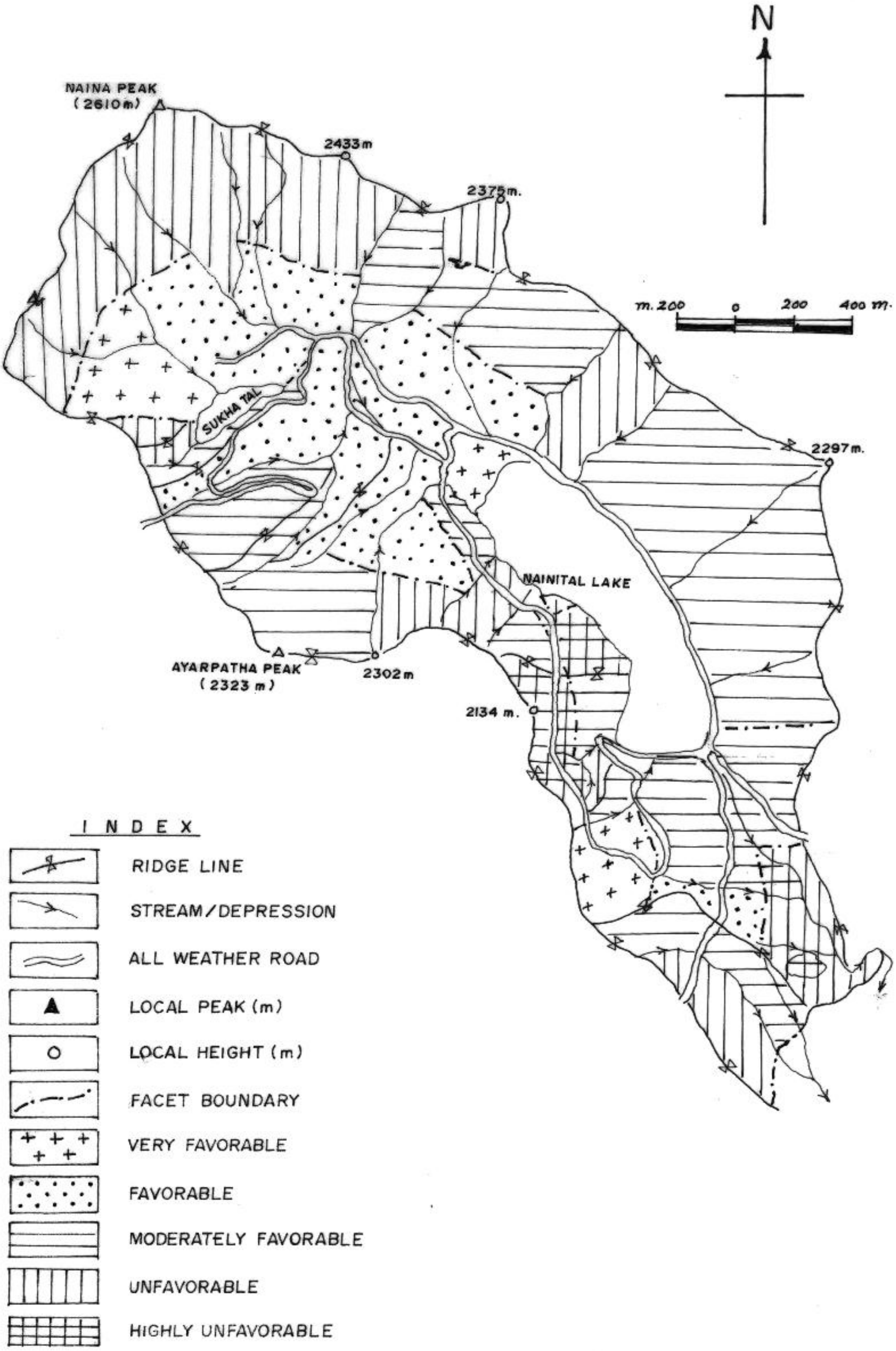


FIG. 13 TYPICAL SLOPE PARAMETER MAP

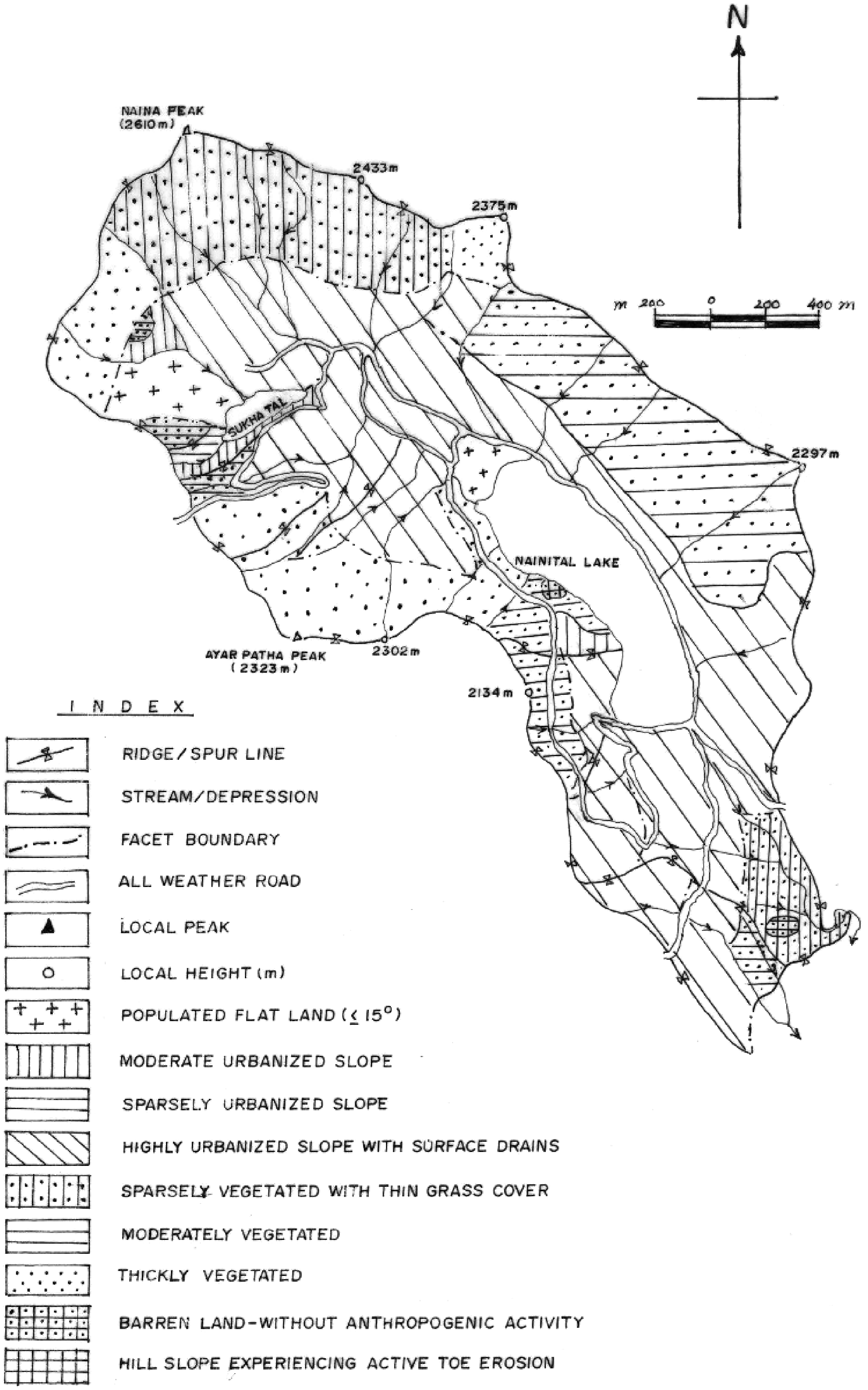


Fig. 14 Typical Land Use & Land Cover Map

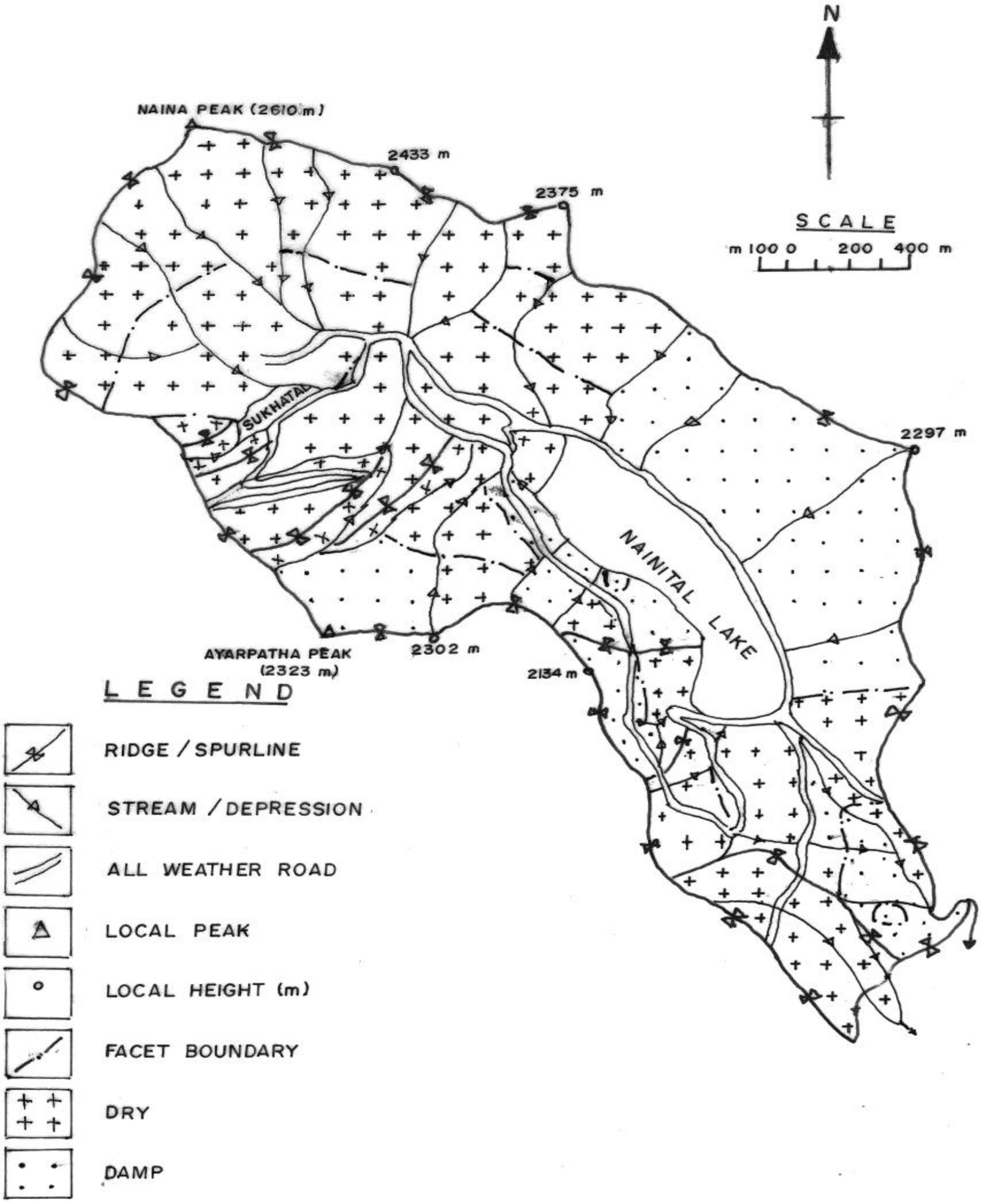


FIG. 15 TYPICAL HYDROGEOLOGICAL MAP

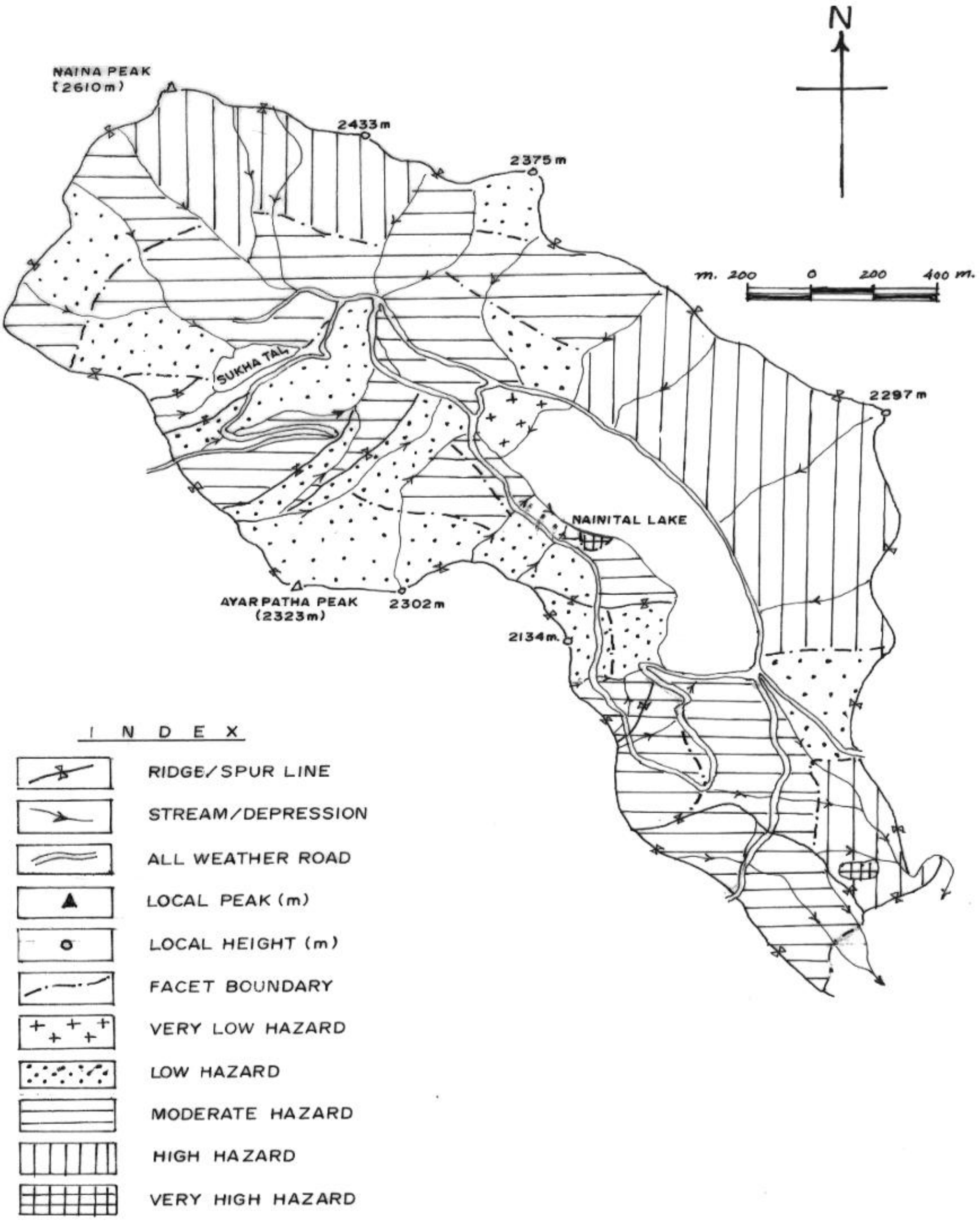


Fig. 16 Typical Meso-Scale (1 : 5,000) Lhz Map

ANNEX A

(*Foreword*)

COMMITTEE COMPOSTION

Hill Area Development Engineering Sectional Committee, CED 56

Organization	*Representative(s)*
In Personal Capacity (*H No-FFA, Block - G Priya Sudarsana Apts, Melur Road, Srirangam Tiruchirappalli, Tami Nadu*)	Dr R. Anbalagan (***Chairman***)
AIMIL Ltd, New Delhi	Shri Sharique Khan Shri Aman Khullar (*Alternate*)
Border Roads Organization, New Delhi	Brig A. K. Das Lt Col Parikshit Mehra (*Alternate*)
Building Materials & Technology Promotion Council, New Delhi	Dr Shailesh Kumar Agarwal
Central Public Works Department, Shillong	Shri Sheo Prasad Singh Shri Prem Chand Mathur (*Alternate*)
Central Soil & Materials Research Station, New Delhi	Dr Manish Gupta Shri Hari Das (*Alternate*)
Central Water Commission, New Delhi	Director HCD (Nw&S) Director (Sardar Sarovar) (*Alternate*)
CSIR - Central Building Research Institute, Roorkee	Shri Ashok Kumar Shri Ajai Chaurasia (*Alternate*)
CSIR - Central Institute of Mining & Fuel Research, Roorkee	Dr R. K. Goel Shri Anil Swarup (*Alternate*)
CSIR - Central Road Research Institute, New Delhi	Dr Kishor Kumar Dr Pankaj Gupta (*Alternate*)
Defence Terrain Research Laboratory/(DRDO), Delhi	Dr L. K. Sinha
Department of Science & Technology, Ministry of Science & Technology, New Delhi	Shri Bhoop Singh
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